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INVESTIGATIONS OF PERMANENT MAGNET ALLOYS BASED ON COBALT AND CERIUM MISCHMETAL

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Résumé. — L'auteur est arrivé à produire de grands champs coercitifs compris entre 4 000 et 5 000 Oe avec des poudres d'alliage MMCo₅, où MM est un mischmetal riche en céritum. Ces résultats sont obtenus après broyage, traitement à l'acide et zinguage par diffusion. On a étudié le durcissement obtenu par précipitation dans MMCo₅-Cu₂. On a obtenu à ce jour les valeurs $\mu H_C = 4 320$ Oe et $M_r/M_p = 0.98$ pour $x = 2$. Ainsi MMCo₅ et MMCo₃Cu₂ sont des matériaux intéressants pour fabriquer des aimants permanents relativement économiques du type RCo₅.

Abstract. — The intrinsic coercivity of powders of MMCo₅ (MM = cerium-mischmetal) could be raised to values between 4 000 and 5 000 Oe by ballmilling, an acid treatment and zinc diffusion coating, alternatively. The precipitation hardening of MMCo₃-Cu₂ was studied and optimized. $\mu H_C = 4 320$ Oe and $M_r/M_p = 0.98$ were achieved for $x = 2$. MMCo₅ and MMCo₃Cu₂ are thus attractive choices for relatively inexpensive permanent magnet materials of the RCo₅ type.

I. Introduction. — Of all the rare earth-cobalt alloys which have utility for permanent magnets [1], those in which the rare earth (R) component is the conventional cerium-rich mischmetal (MM) (¹) are the economically most attractive at this time. However, the properties of MMCo₅ powders prepared by normal grinding techniques are not good enough. The intrinsic coercive force of particles that can be well oriented appeared limited to $M_r = 2 500$ Oe [2, 3]. Higher values, to $> 4 000$ Oe, could be achieved only by means that also largely destroyed the needed particle anisotropy [4]. This paper is a report about successful attempts to apply to MMCo₅ various methods of improving the coercivity which had previously been tried on powders of other related substances.

II. Grinding in Liquid Nitrogen. — Since the $H_r$ limitations are attributed to plastic deformation of the particles, grinding in a more brittle state at low temperatures had been suggested and tried before with indications of improvement [1, 4]. We ground in an attritor mill [3, 5], with balls and powder immersed in liquid nitrogen (LN), and measured hysteresis loops on aligned, epoxy-bonded, dilute samples. Figure 1 shows the results of grinding two different ingots in LN and for comparison in iso-octane at room temperature. Coercivities up to 4 550 Oe with a loop squareness of $M_r/M_p = 0.78$ were obtained. Such fine powders were pyrophoric in air at room temperature after the LN had evaporated.

III. Particle Surface Treatments. — Becker [6] described methods of improving the coercivity of YCo₅ and SmCo₅ particles, produced by normal grinding, by removing their strongly deformed, oxidized and irregularly shaped surface layer in an acid bath, or magnetically deactivating it with zinc. We have beneficially applied both methods first to PrCo₅ [5] and now to MMCo₅. Figure 2a, b shows the improvements obtained on mortar-ground powders that were soaked for 8 minutes in a solution of 1 part

(¹) MM = Ronson Ceralloy 100 X. Analysis : 54.5 weight % Ce, 26 La, 13 Nd, 5 Pr, remainder mostly other rare earths.
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IV. Precipitation Hardening of MM(Co, Cu)$_5$ alloys.—SmCo$_5$, CeCo$_5$, and solid solutions of these can be magnetically hardened in bulk, form by substituting copper or Cu + Fe for a part of the cobalt [7, 8] but an earlier attempt to do this with MMCo$_5$ failed [3]. We investigated a series of alloys of the type MMCo$_{5-x}$Cu$_x$, varying composition and heat treatment. The alloys were produced by arcmelting. Hysteresis loops were measured on coarse (74-105 µm), magnetically aligned particles, which act essentially like grain-oriented, massive material. Figure 3 summarizes coercive-force data for all alloys in various states of heat treatment. The optimum properties, $H_c = 4320$ Oe with excellent loop squareness ($M_r/M_p = 0.98$), were obtained for an alloy of $x = 2$, homogenized at 1100°C, cooled moderately slowly in a quartz bulb in stagnant air and then held four hours at 500°C. This alloy has a saturation $4\pi M_s = 5350$ G. Energy products up to 7 MG Oe should thus be possible for massive pieces.

Figure 4 shows the dependence of $H_c$ on the heat treatment for two of the compositions. The final heat treatment does little to improve the properties of the slow-cooled alloy, but it can nearly completely restore the coercivity after lowering the latter drastically by solution annealing and quenching.

V. Summary.—By four different methods, the intrinsic coercive force of simple or Cu-modified MMCo$_5$ could be raised to values between 4000 and 5000 Oe, and good particle alignment was achieved. This should permit fabrication of magnets that are nearly equivalent to PtCo. It makes MMCo$_5$ an attractive choice among the new magnet alloys of the RCo$_5$ type.

References